Status of Level 2 Product and IEEE Paper Presentation to AIRS Science Team

May 2 , 2002

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Simulation Shown in Paper

December 15, 2000 Granule 401

Results run at GSFC

- Necessary to provide certain statistics

Simulations at central golfball angle

- McMillin's angle correction is not installed yet at GSFC

Simulations use old first product code

- We generate the first product retrievals
- We do not have new code or coefficients

Simulations use perfect physics

- No tuning done

Changes Since Last Team Meeting

* Used updated microwave product (as of April 1, 2000)
We use product generated at JPL

* Did not reject based on NOAA score
Significantly improved yield

** Rejected cases if microwave product liquid water > 0.03 gm/cm^2
Used to not be a rejection criterion

** Rejected cases if retrieved cloud fraction > 80%
Used to be > 90%

** Limited noise covariance contribution for liquid water uncertainty

** Slightly modified error propagation equation
Theorectically better
In practice, little difference

* Currently installed at JPL

** Will be installed in version 2.2.4

References to AIRS IEEE Papers

Aumann et al. (2002)

Instrument description, including noise

Rosenkranz (2000)

Microwave product

Goldberg et al.(2002)

First product (we do not use this however)

Adjustment of radiances to central golfball angle (we did not do this)

Fishbein et al. (2002)

Simulation methodology

McMillin et al. (2002)

Tuning methodology (acknowledge method exists)

RETRIEVAL OF ATMOSPHERIC AND SURFACE PARAMETERS FROM AIRS/AMSU/HSB DATA UNDER CLOUDY CONDITIONS

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ABSTRACT

New state of the art methodology is described to analyze AIRS/AMSU/HSB data in the presence of multiple cloud formations. The methodology forms the basis for the AIRS Science Team algorithm which will be used to analyze AIRS/AMSU/HSB data on EOS Aqua. The cloud clearing methodology requires no knowledge of the spectral properties of the clouds. The basic retrieval methodology is general and extracts the maximum information from the radiances, consistent with the channel noise covariance matrix. The retrieval methodology minimizes the dependence of the solution on the first guess field and the first guess error characteristics. Results are shown for AIRS Science Team simulation studies with multiple cloud formations. These simulation studies imply that clear column radiances can be reconstructed under partial cloud cover with an accuracy comparable to single spot channel noise in the temperature and water vapor sounding regions, temperature soundings can be produced under partial cloud cover with RMS errors on the order of, or better than, 1°K in 1 km thick layers from the surface to 700 mb, 1 km layers from 700 mb to 300 mb, 3 km layers from 300 mb to 30 mb, and 5 km layers from 30 mb to 1 mb, and moisture profiles can be obtained with an accuracy better than 20% absolute errors in 1 km layers from the surface to nearly 200 mb.

1. INTRODUCTION

AIRS (Atmospheric Infrared Sounder) is a high spectral resolution ($\lambda/\Delta\lambda \approx$ 1200) infrared sounder, with 2378 channels covering the spectral domain 650 cm^{-1} - 2675 cm^{-1}, which will fly on the EOS Aqua platform in 2002, accompanied by the AMSU A (Advanced Microwave Sounding Unit A) and HSB (Humidity Sounder for Brazil, which is similar to AMSU B). The AIRS footprint is 13 km at nadir, as is the HSB footprint, with a 3x3 array of AIRS and HSB footprints falling into a single AMSU A footprint. Characteristics of the AIRS instrument are given in Aumann et al., 2002.

Susskind et al., 1998 described the first version of the methodology used by the AIRS Science team to analyze AIRS/AMSU/HSB data in the presence of clouds to determine surface skin temperature, surface spectral emissivity and bi-directional reflectance, atmospheric temperature-moisture-ozone profile, and the heights and amounts of different layers of clouds in the fields of view. Two important characteristics of the basic retrieval methodology are that no assumptions are needed about the spectral properties of the clouds and no assumptions are needed about the intrinsic accuracy of the first guess field used to start the iterative process. This paper describes further theoretical improvements in the retrieval and cloud clearing methodology incorporated in the current version of the AIRS Science team algorithm which will be used to analyze AIRS/AMSU/HSB data on the EOS Aqua platform. The following sections will describe the basic methodology used to estimate cloud cleared AIRS radiances, which are subsequently used to retrieve surface and atmospheric geophysical parameters other than cloud parameters as well as to derive the effects of clouds on the channel noise covariance matrix; describe the inversion methodology, which makes strong use of the channel noise covariance matrix and is applicable to solving for all the geophysical parameters including cloud parameters; and show sample results from AIRS Science Team simulations.

2. CLOUD CLEARING METHODOLOGY

Clouds have a significant effect on observed infra-red radiances, and can have smaller but non negligible effects on microwave observations as well. Therefore,

Juang, H-M., S. Y. Hong, and M. Kinamitsu, "The NCEP Regional Spectral Model: An Upate." Bull. Am. Meteor. Soc., 78, 2125-2128, 1997.

Kaplan, L. D., M. T. Chahine, J. Susskind, and J. E. Searl, "Spectral Band Passes for a High Precision Satellite Sounder." Appl. Opt., 16, 322-325, 1977.

Mehta, A. and J. Susskind, "Outgoing Longwave Radiation from the TOVS Pathfinder Path A Data Set." J. Geophys. Res., 104, 12193-12212, 1999a.

Metha, A. and J. Susskind, "Longwave Radiative Flux Calculations in the TOVS Pathfinder Path A Data Set." NASA CR 1999-208643, Greenbelt, Md., 1999b.

McMillin, L. M., and C. Dean, "Evaluation of a New Operational Technique for Producing Clear Radiances." J. Appl. Meteor., 21, 1005-1014, 1982.

McMillin, L., M. Goldberg, S. Zhou, and H. J. Ding, "AIRS Validation and Tuning." IEEE Rem. Sens., 2000.

Rodgers, C. D., Retrieval of Atmospheric Temperature and Composition from Remote Measurements of Thermal Radiation. Rev. Geophys. and Space Phys., 14, 609-624, 1976.

Rosenkranz, P. W., "Retrieval of Temperature and Moisture Profiles from AMSU-A and AMSU-B Measurements." IGARSS, 2000.

Smith, W. L., "An Improved Method for Calculating Tropospheric Temperature and Moisture from Satellite Radiometer Measurements." Mon. Wea. Rev., 96, 387-396, 1968.

Susskind, J., C. Barnet, and J. Blaisdell, "Determination of Atmospheric and Surface Parameters from Simulated AIRS/AMSU/HSB Sounding Data: Retrieval and Cloud Clearing Methodology." Adv. Space Res., 21, 369-384, 1998.

Susskind, J., P. Piraino, L. Rokke, L. Iredell, a A. Mehta, Characteristics of the TOVS Pathfind Path A Data Set. Bull. Am. Met. Soc., 78, 144 1472, 1997.

Twomey, S., "On the Numerical Solution of t Fredholm Integral Equations of the First Kind Inversion of the Linear System Produced Quadrature." J. Assoc. Comp. Mach., 10, 79-1C 1963.

Also shown in the third panel of the RMS statistics is the single spot channel noise.

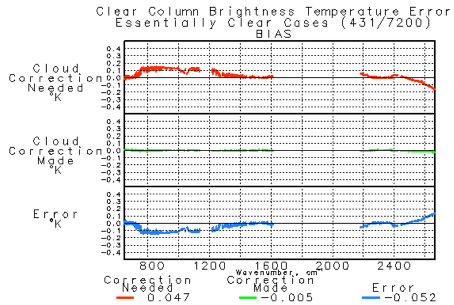


Figure 3a. Mean value of cloud correction needed, cloud correction made, and errors of cloud cleared brightness temperature for essentially clear cases.

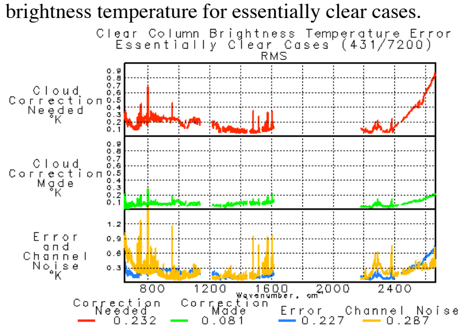


Figure 3b. RMS values of cloud correction needed, cloud correction made, and cloud cleared brightness temperature errors for essentially clear spots. Single spot noise is also shown.

In the mean sense, “essentially clear” spots needed an average cloud correction of roughly 0.1K in the 800cm^{-1} – 1150 cm^{-1} region, and essentially none was made on the average. This resulted in a small cold bias in this window region in the reconstructed clear column brightness temperatures. In the RMS sense, corrections of up to 0.25K were needed in the long wave window for these cases (some of this is due to channel noise) and corrections of about 0.1K were made. For the most part, the RMS values of t he reconstructed brightness temperatures were comparable to, or smaller than, the single spot channel noise. Lower values can arise if either the channel is considered not to see clouds (the noise amplification factor is 1/3) or the scene is considered clear or contains very small values of ▯, resulting noise amplification factors less than 1, provid accurate values of ▯ a re obtained. Radiances f “essentially clear” cases are definitely suitable f data assimilation purposes.

Figure 4 sh ows analogous statistics for the 46(accepted cases for all cloud conditions. On t average, cloud corrections of almost 12K were need in the longwave window region, and the correctio made was slightly smaller than needed, with about 0.5K negative bias in r econstructed clear colun brightness temperatures at t he worst frequencies. the RMS sense, reconstructed clear column brightne temperatures were still comparable to channel noi throughout most of the temperature profile soundi regions (650 cm^{-1} – 750 cm^{-1} and 2200 cm^{-1} – 24(cm^{-1}), but larger than the noise elsewhere in t spectrum. RMS errors in the water vapor soundi region are still very small and radiances in the channels, as well as those in the temperature soundi region, should be suitable for data assimilation. V encourage researchers in the field of data assimilati to test the use of radiances for all accepted case This would substantially increase the number of cas which can be used and should further impro forecast skill compared to use of radiances in ju clear or essentially clear cases.

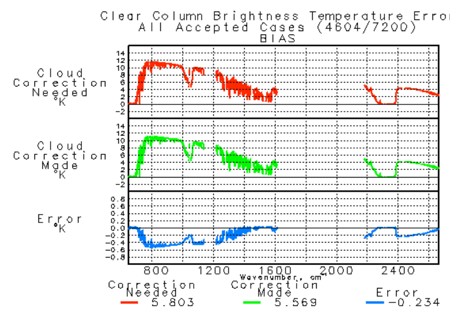
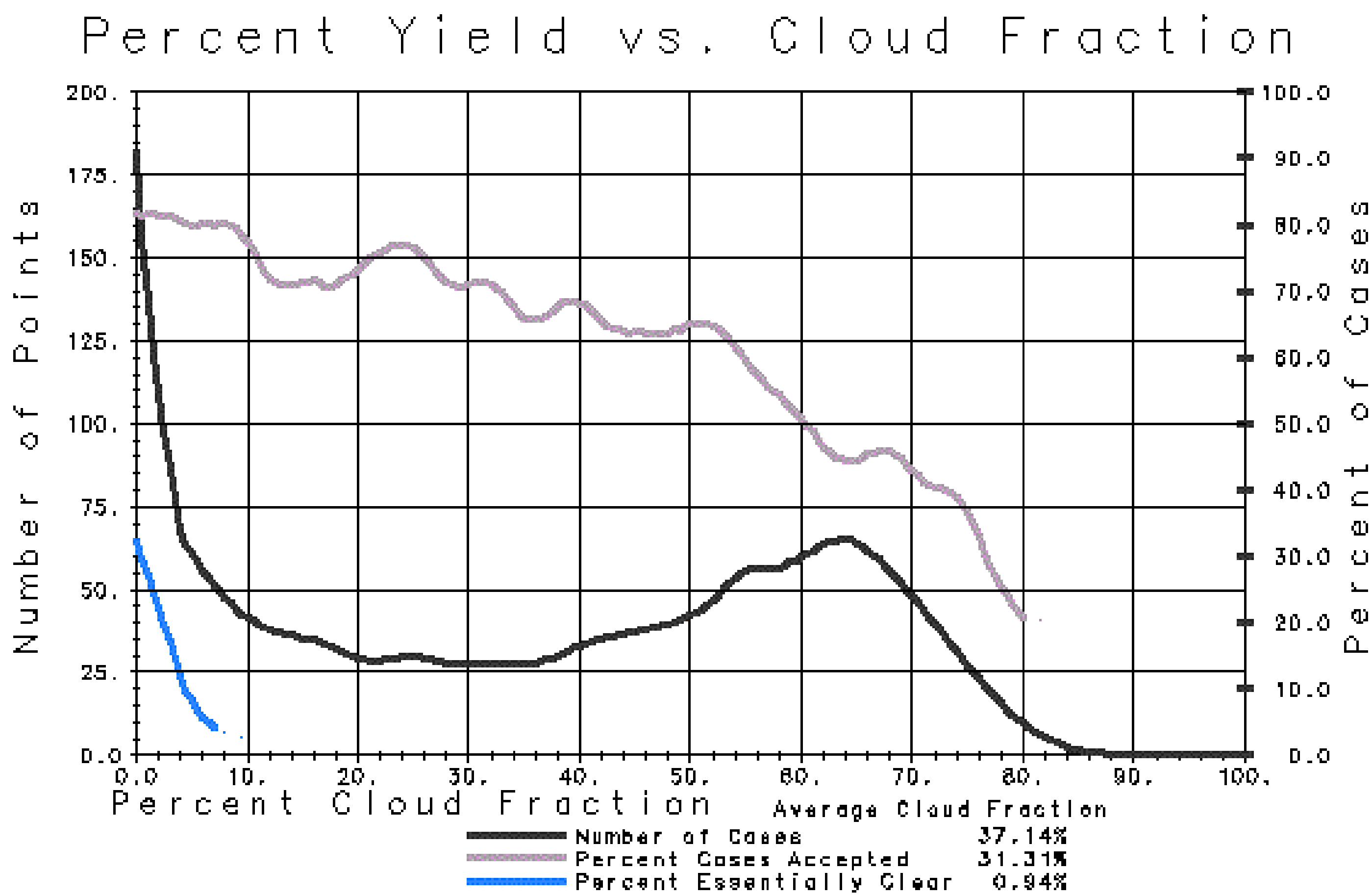
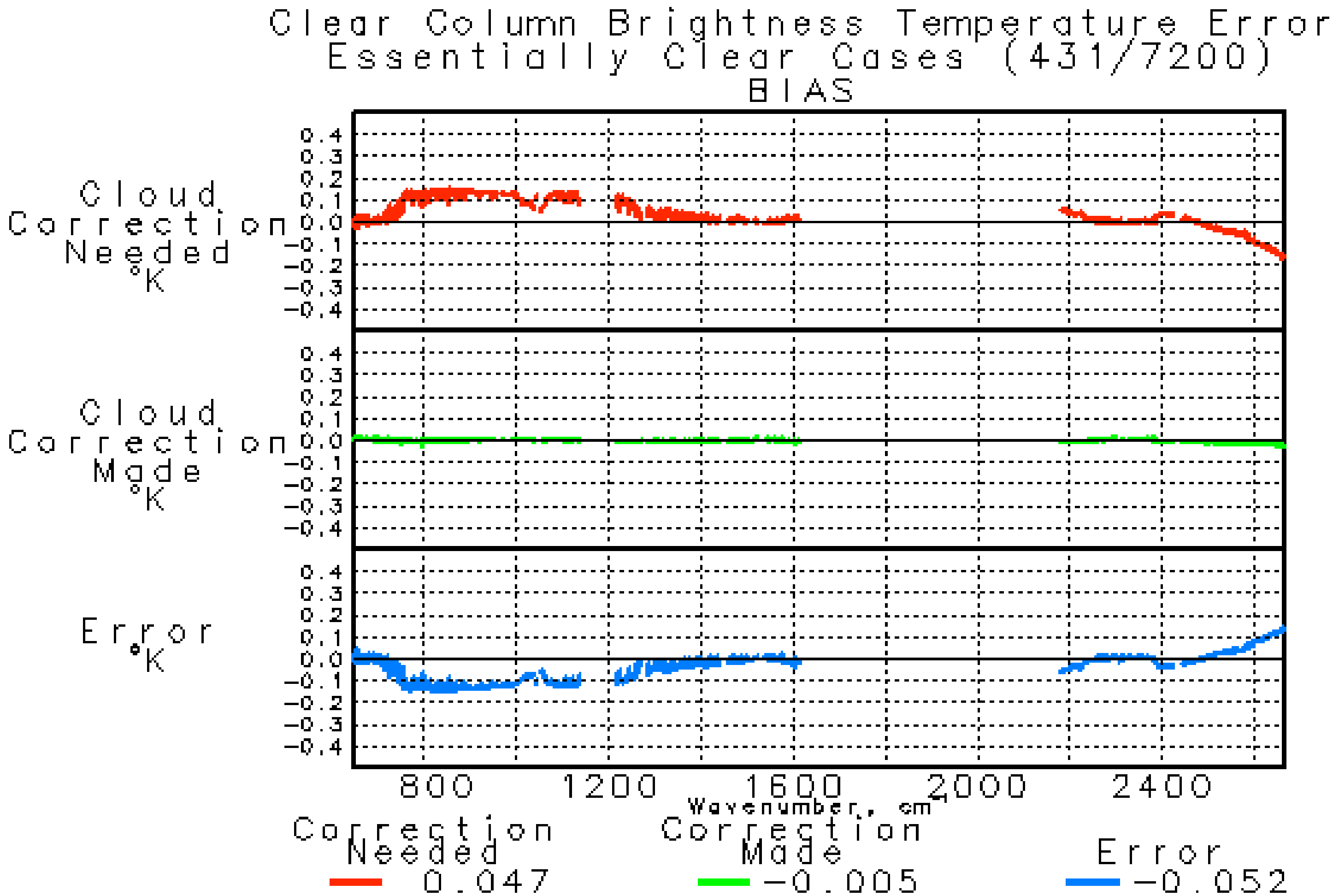
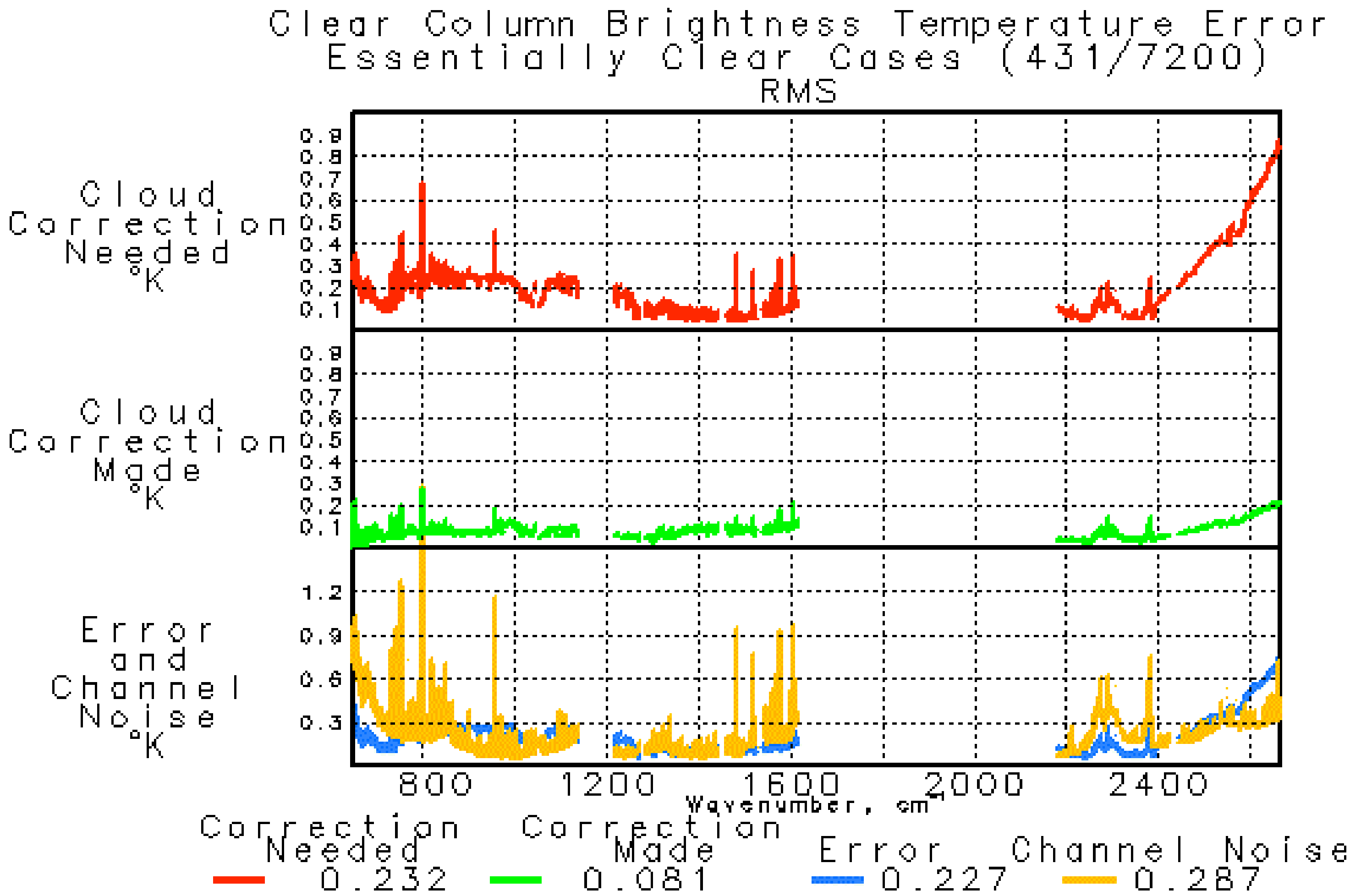


Figure 4a. Mean values of cloud correction needed, cloud correction made, and errors of cloud cleared brightness temperatures for all accepted cases.

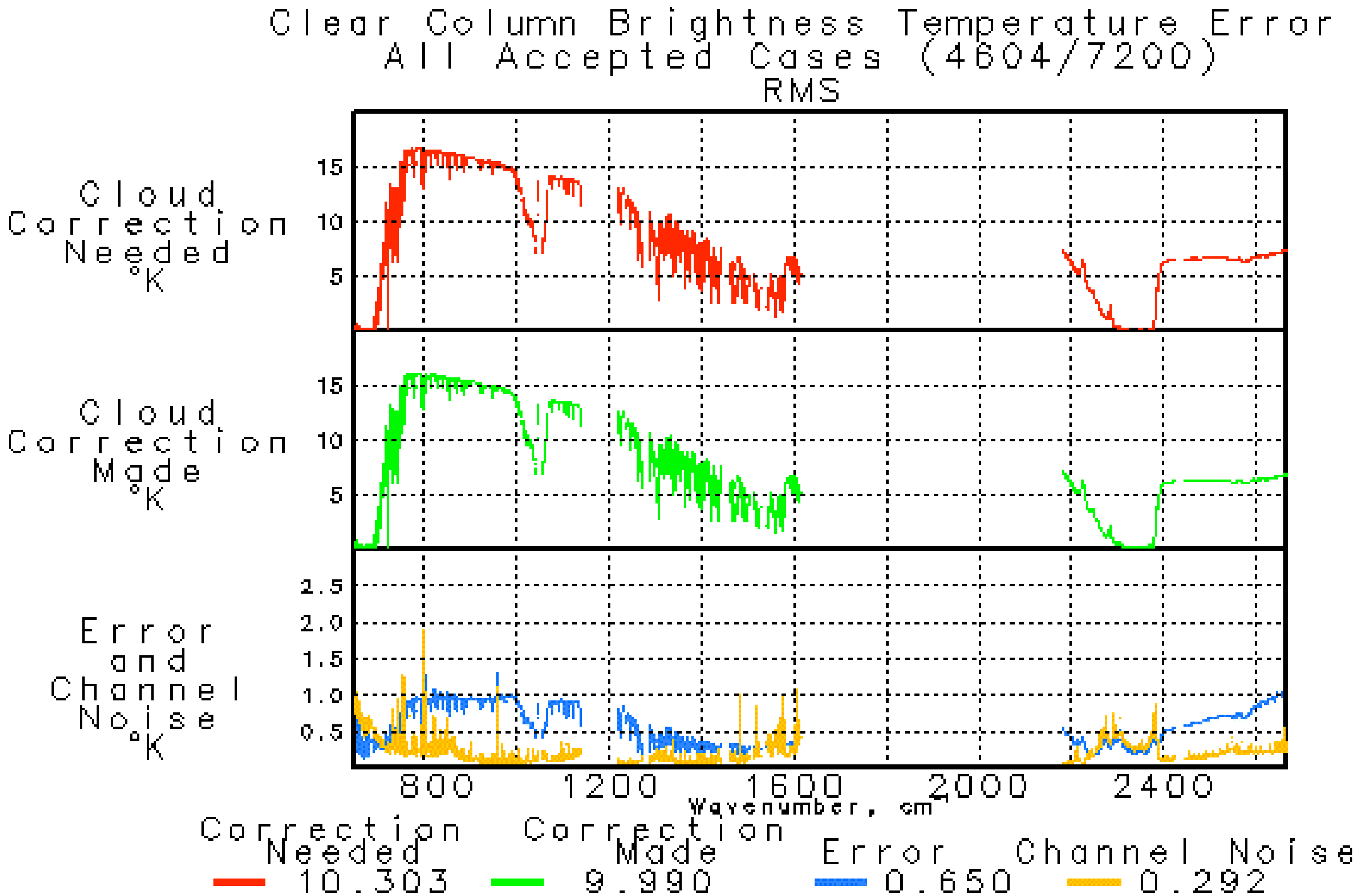

Percent Yield vs. Cloud Fraction
Number of Points
Percent of Cases
Percent Cloud Fraction
200.
175.
150.
125.
100.
75.
50.
25.
0.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.
Average Cloud Fraction
Number of Cases 37.14%
Percent Cases Accepted 31.31%
Percent Essentially Clear 0.94%

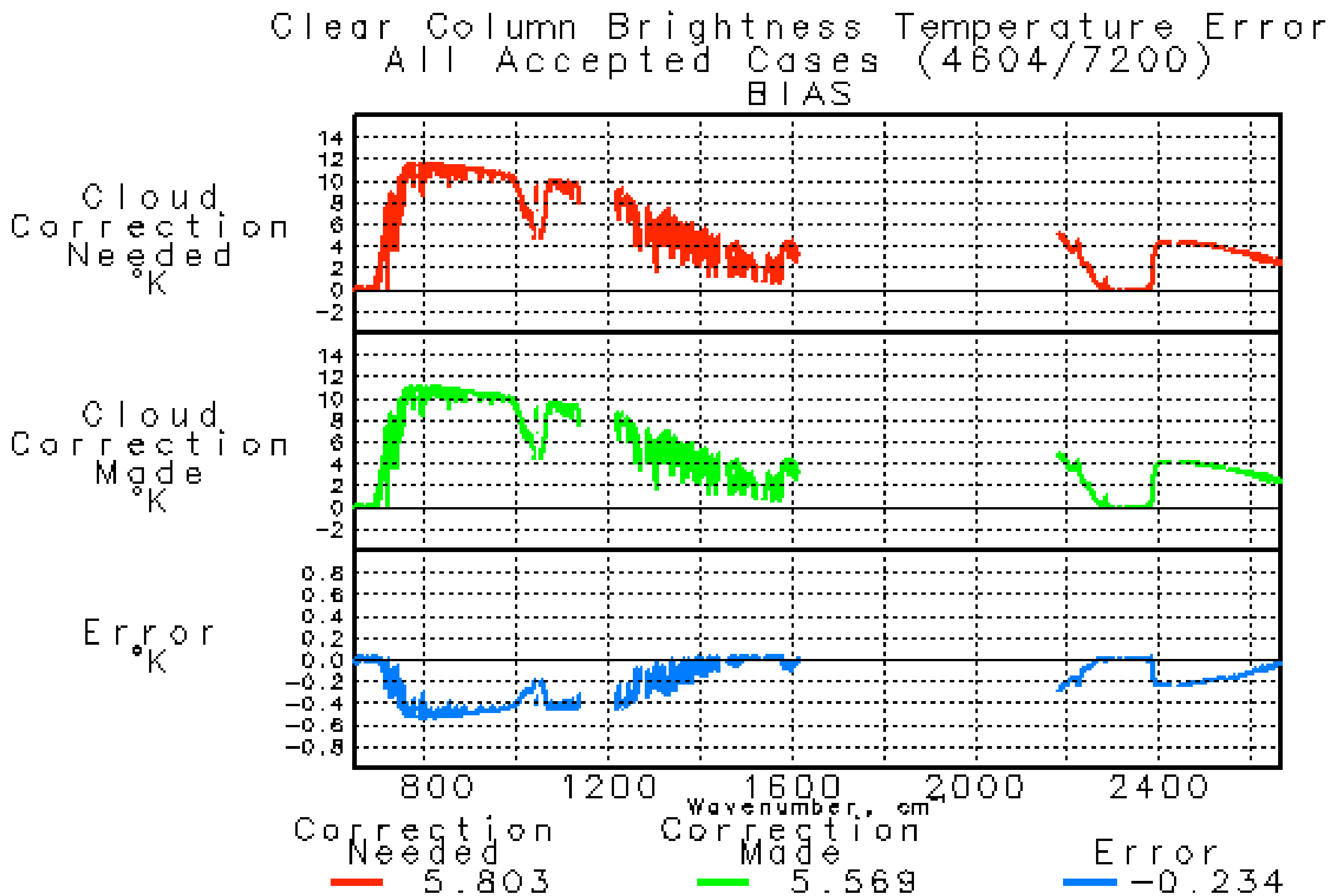


Clear Column Brightness Temperature Error
Essentially Clear Cases (431/7200)
BIAS
Cloud Correction Needed °K
Cloud Correction Made °K
Error °K
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
800
1200
1600
2000
2400
Wavenumber, cm⁻¹
Correction Needed 0.047
Correction Made −0.005
Error −0.052



Clear Column Brightness Temperature Error
Essentially Clear Cases (431/7200)
RMS
Cloud Correction Needed °K
Cloud Correction Made °K
Error and Channel Noise °K
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1.2
0.9
0.6
0.3
800
1200
1600
2000
2400
Wavenumber, cm⁻¹
Correction Needed 0.232
Correction Made 0.081
Error 0.227
Channel Noise 0.287

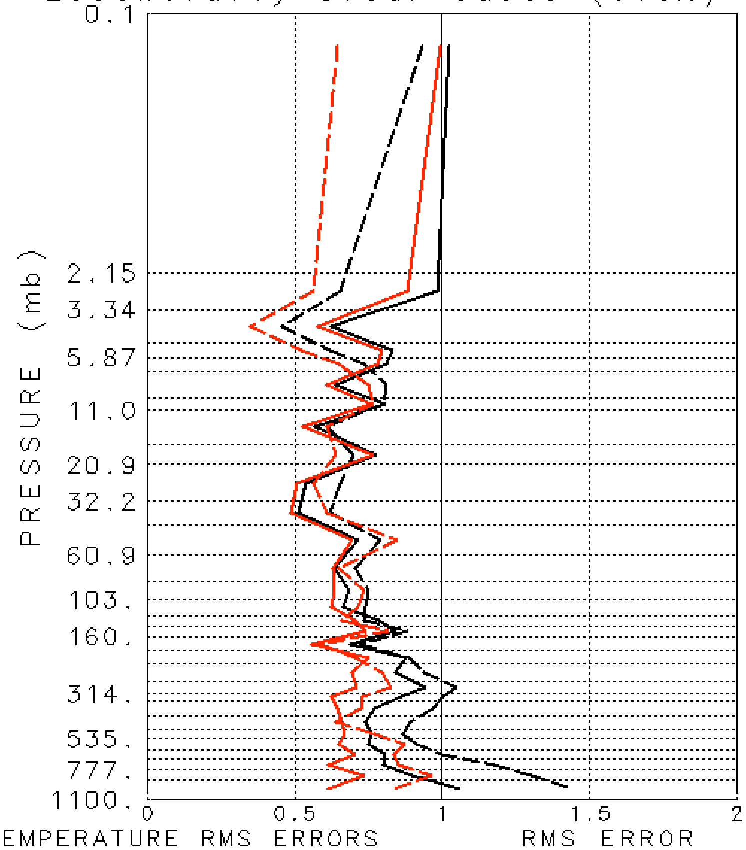

Clear Column Brightness Temperature Error
All Accepted Cases (4604/7200)
RMS
Cloud Correction Needed °K
Cloud Correction Made °K
Error and Channel Noise °K
15
10
5
2.5
2.0
1.5
1.0
0.5
800
1200
1600
2000
2400
Wavenumber, cm
Correction Needed 10.303
Correction Made 9.990
Error 0.650
Channel Noise 0.292


Clear Column Brightness Temperature Error
All Accepted Cases (4604/7200)
BIAS
Cloud Correction Needed °K
Cloud Correction Made °K
Error °K
14
12
10
8
6
4
2
0
-2
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
800
1200
1600
2000
2400
Wavenumber, cm⁻¹
Correction Needed 5.803
Correction Made 5.569
Error -0.234

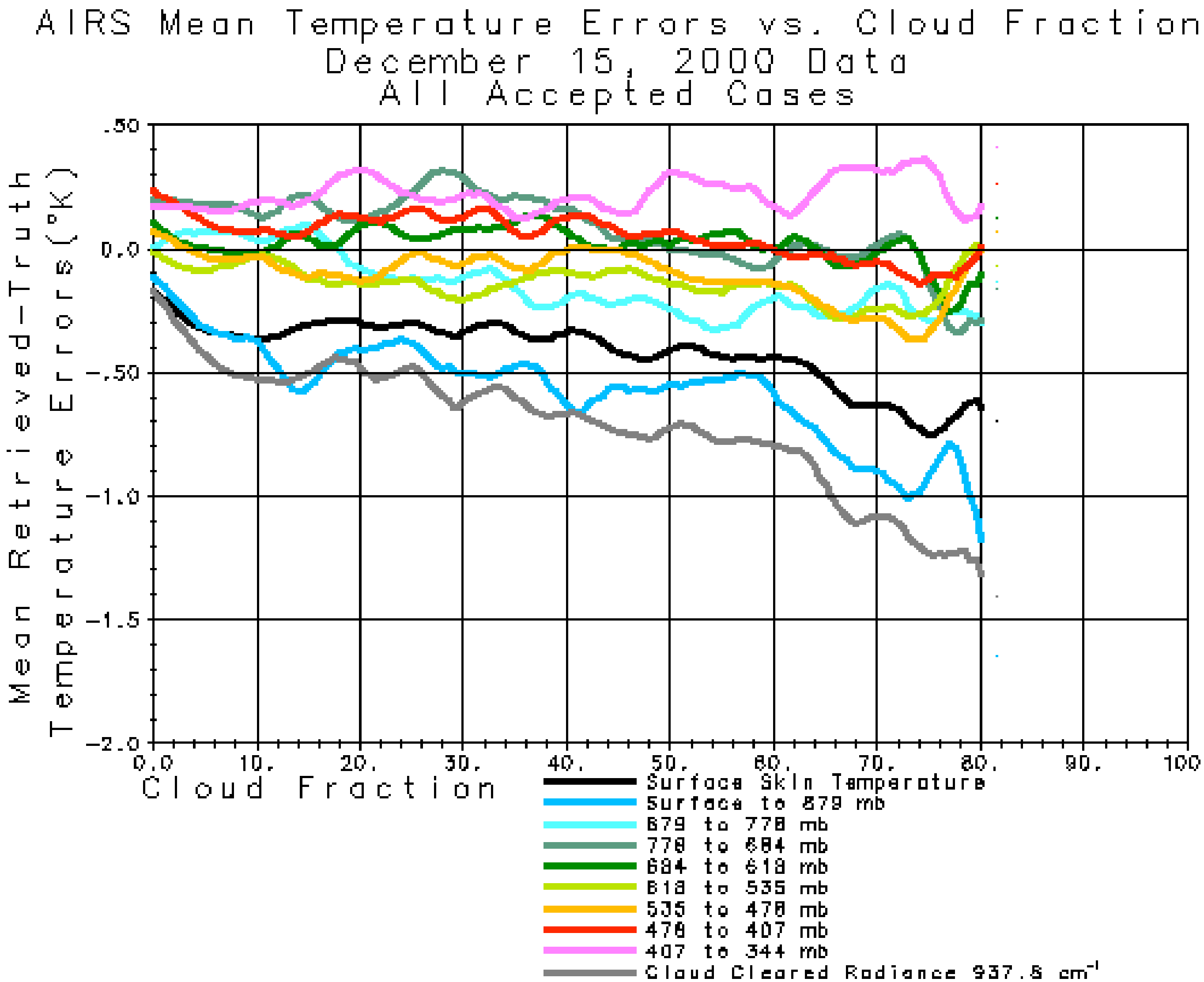
LAYER MEAN RMS TEMPERATURE ERRORS (°C)

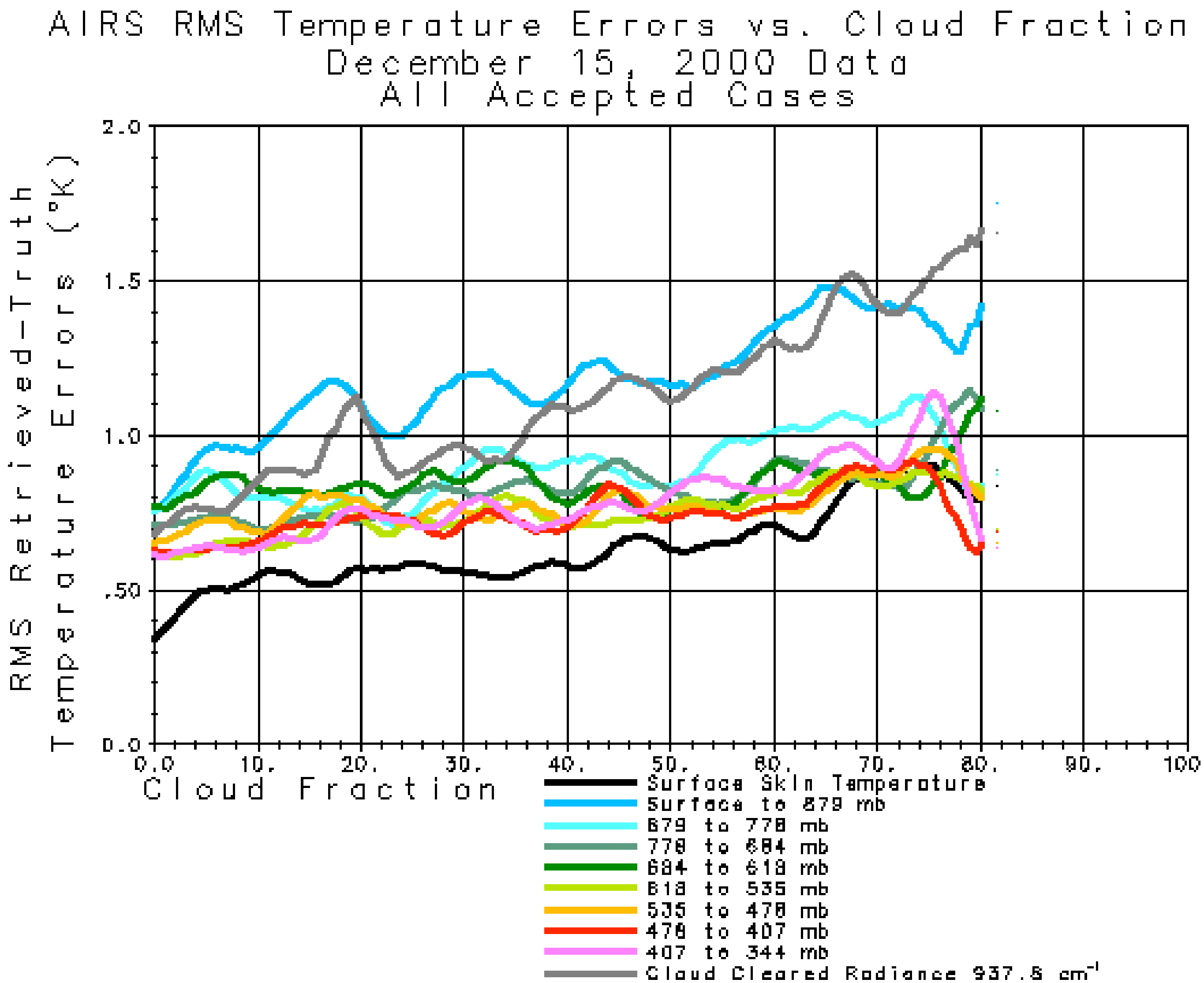
All Accepted Cases (63.9%)

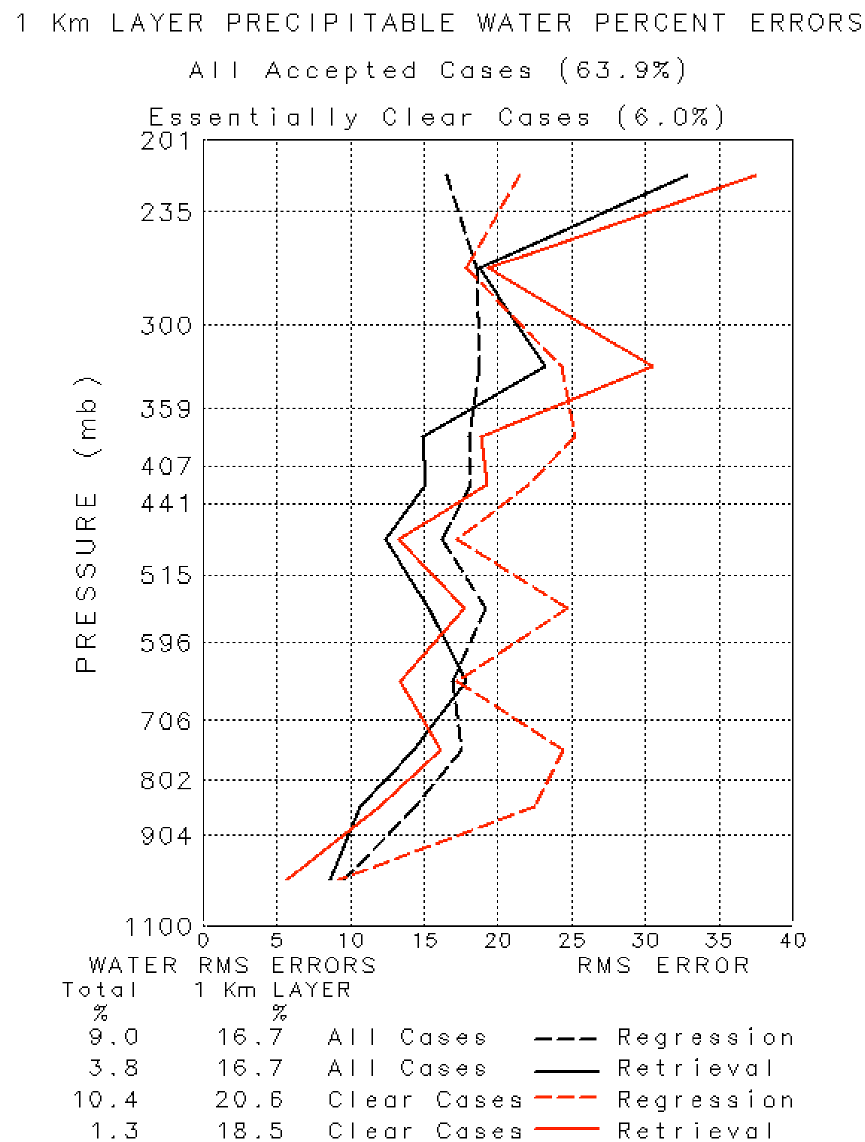
Essentially Clear Cases (6.0%)



SKIN TEMP	STATISTICS trop	700-surf		
1.45	0.97	1.31	All Cases	Regression
0.59	0.82	0.92	All Cases	Retrieval
0.50	0.77	0.88	Clear Cases	Regression
0.25	0.67	0.65	Clear Cases	Retrieval


AIRS Mean Temperature Errors vs. Cloud Fraction
December 15, 2000 Data
All Accepted Cases
Mean Retrieved-Truth
Temperature Errors (°K)
.50
0.0
-.50
-1.0
-1.5
-2.0
0.0
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.
Cloud Fraction
Surface Skin Temperature
Surface to 879 mb
879 to 778 mb
778 to 684 mb
684 to 618 mb
618 to 535 mb
535 to 478 mb
478 to 407 mb
407 to 344 mb
Cloud Cleared Radiance 937.8 cm⁻¹


AIRS RMS Temperature Errors vs. Cloud Fraction
December 15, 2000 Data
All Accepted Cases
RMS Retrieved-Truth
Temperature Errors (°K)
2.0
1.5
1.0
.50
0.0
0.0
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.
Cloud Fraction
Surface Skin Temperature
Surface to 879 mb
879 to 778 mb
778 to 684 mb
684 to 618 mb
618 to 535 mb
535 to 478 mb
478 to 407 mb
407 to 344 mb
Cloud Cleared Radiance 937.5 cm-1



1 Km LAYER PRECIPITABLE WATER PERCENT ERRORS
All Accepted Cases (63.9%)
Essentially Clear Cases (6.0%)
PRESSURE (mb)
201
235
300
359
407
441
515
596
706
802
904
1100
0
5
10
15
20
25
30
35
40
RMS ERROR
WATER RMS ERRORS
Total
1 Km LAYER
%
%
9.0
16.7
All Cases
Regression
3.8
16.7
All Cases
Retrieval
10.4
20.6
Clear Cases
Regression
1.3
18.5
Clear Cases
Retrieval

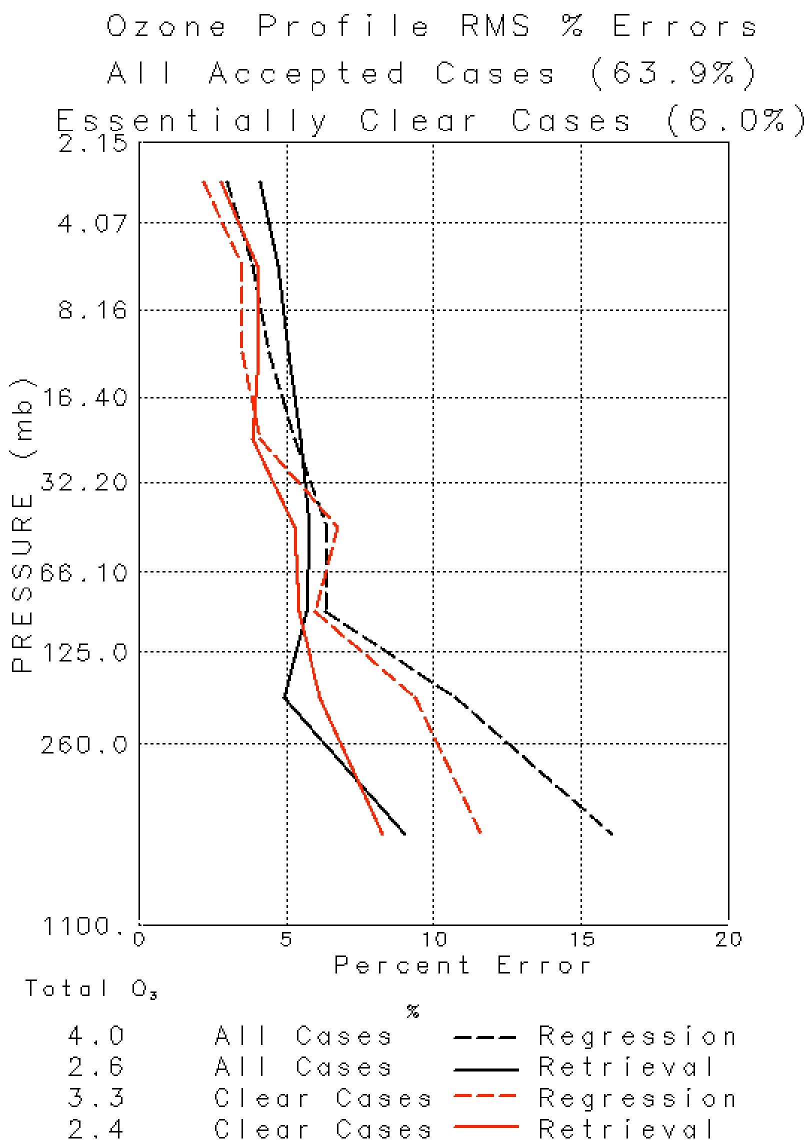

Ozone Profile RMS % Errors
All Accepted Cases (63.9%)
Essentially Clear Cases (6.0%)
PRESSURE (mb)
2.15
4.07
8.16
16.40
32.20
66.10
125.0
260.0
1100.
0
5
10
15
20
Percent Error
Total O_3
%
4.0 All Cases Regression
2.6 All Cases Retrieval
3.3 Clear Cases Regression
2.4 Clear Cases Retrieval

Table 4. Retrieved Cloud Fraction and OLR Errors

	Accepted Cases	Rejected Cases
Number	4604	2522
Average Cloud Cover	31.31%	47.12%
Bias	1.98%	-1.17%
RMS Error	6.33%	11.75%
Average OLR	221.8 W/m^2	196.2 W/m^2
Bias	-1.28 W/m^2	0.38 W/m^2
RMS Error	2.94 W/m^2	5.20 W/m^2
Average CLR OLR	253.0 W/m^2	238.8 W/m^2
Bias	-1.60 W/m^2	-1.81 W/m^2
RMS Errors	2.57 W/m^2	6.76 W/m^2

Required Additions to GSFC Code to Analyze Real Data

Install level 1B HDf interface

Install new first product regression code

- Microwave product code is currently being installed

Install tuning

- Develop preliminary tuning based on AMSU radiances
- Install NOAA tuning

Arrange to get forecast guess

    - NCEP?, ECMWF?
    - Need for surface pressure, generating tuning coefficients

Planned Experiments at GSFC

Launch +3 months to launch +6 months

- Generate preliminary tuning coefficients using early transmittances
- Run tuned retrievals for clear cases skipping first product step
  - Skipping first product reduces yield, but not accuracy
- Test retrievals under cloudy conditions
- Update as regression coefficients, tuning coefficients, and new transmittances become available

Launch +6 months to launch +9 months

- Optimize retrieval system
- Deliver updated level 2 algorithm to be used by DAAC

Launch +9 months to launch +12 months

- Run at least 1 month of global retrievals
  - Give results to DAO for data assimilation experiments
  - Generate monthly mean products and compare with Pathfinder results